

TESTING OF A 40-125 μm PROTOTYPE ARRAY FOR AIRBORNE ASTRONOMY

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ABSTRACT

Testing of a 40-125 μm Ge:Sb photoconductor prototype array for AIRES (Airborne Infra-Red Echelle Spectrometer) is described. The prototype is a 2x24 module which can be close-stacked to provide larger two-dimensional formats. Collecting cones on a 2 mm pitch concentrate incident light into integrating cavities containing the detectors. The array is read out by two Raytheon SBRC 190 cryogenic multiplexers that also provide a CTIA (capacitive transimpedance amplifier) unit cell for each detector. We are conducting a series of tests to measure the array performance and to evaluate its suitability for airborne astronomy and report here preliminary results.

INTRODUCTION

We have assembled and started testing a 2x24 Ge:Sb photoconductor prototype array for AIRES (Airborne Infra-Red Echelle Spectrometer). AIRES is a high resolution spectrometer designed for use on SOFIA (Stratospheric Observatory for Infrared Astronomy). It will use three separate arrays to completely cover the 16-210 μm wavelength range. The prototype discussed in this paper is for the 40-125 μm range where astrophysically interesting lines such as [O III] (52, 88 μm), [N II] (57 μm), [O I] (63 μm), [N II] (122 μm), CO (118, 100, 87 μm) and the OH doublets (84, 119 μm) reside. Ge:Sb photoconductors were chosen over the more mature Ge:Ga detectors because of their longer wavelength cutoff¹.

We have set forth on a plan to characterize the array performance. The figures of merit of dark current, responsivity, noise equivalent power (NEP) and detective quantum efficiency (DQE) will be determined to establish the optimal operating conditions. Our first generation of tests will use a fixed illumination source. Later tests will implement chopping and nodding. At this point, we have characterized the system dark current and compare it to the results of Reference 1.

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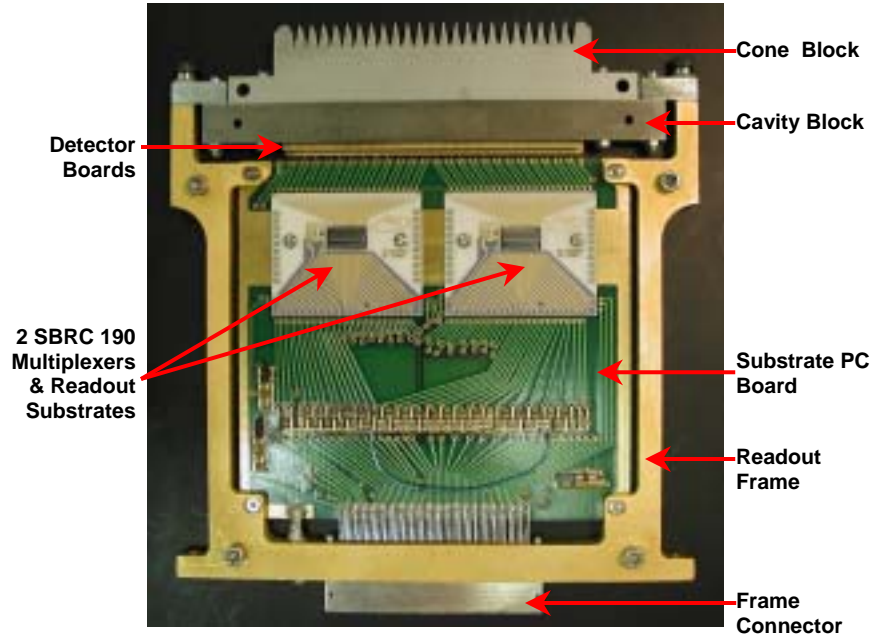


Figure 1: AIRES prototype array ready for mounting into the test dewar.

ARRAY DESCRIPTION

The prototype array uses 48 Ge:Sb photoconductors grown and diced at Lawrence Berkeley National Lab (LBL). Reference 1 discusses the performance of Ge:Sb detectors cut from two crystals (830-6.3 & 831-7.2) and compare their results to a Ge:Ga sample. Our detectors are 1 mm x 1 mm x 2.5 mm discrete chips cut from crystal 831-7.2. Half were cut with a peaked top into a 'house' shape, while the other half were cut with a sloped top into a 'shed' shape. We will evaluate the relative performance of the two detector shapes.

The prototype array is a single 2x24 module. Multiple modules can be close-stacked to provide larger two-dimensional formats. The detectors are glued onto an alumina board, which is in turn glued onto a cavity block. Two cavity blocks attach to a cone block of 2 mm pitch used to concentrate incident light into the integrating cavities containing the detectors. The cavity blocks and cone block are bolted to a readout frame^{2,3}. The Raytheon SBRC 190 cryogenic multiplexer with a capacitive transimpedance amplifier (CTIA) unit cell has been developed to read out the arrays³. Two multiplexers are epoxied on ceramic substrates which are mounted to the readout frame. Wire bonds carry the detector signals from the detector mounting board to the readout substrate. The output signals and bias/clock signals for the readouts are passed to a fan out board through a Nanonics connector at the base of the readout frame. These components for a single module as shown in Figure 1.

TEST APPARATUS

The array is housed in a helium-cooled dewar. The helium bath pressure is controlled by a mechanical pump to ~3 torr, cooling the bath to ~1.5 K. Special care was taken to shield the array from extraneous radiation by enclosing it in two helium temperature shrouds. The dewar shell and all radiation shields have apertures to allow for an external light source. However, at present, these are all blanked off. Two internal

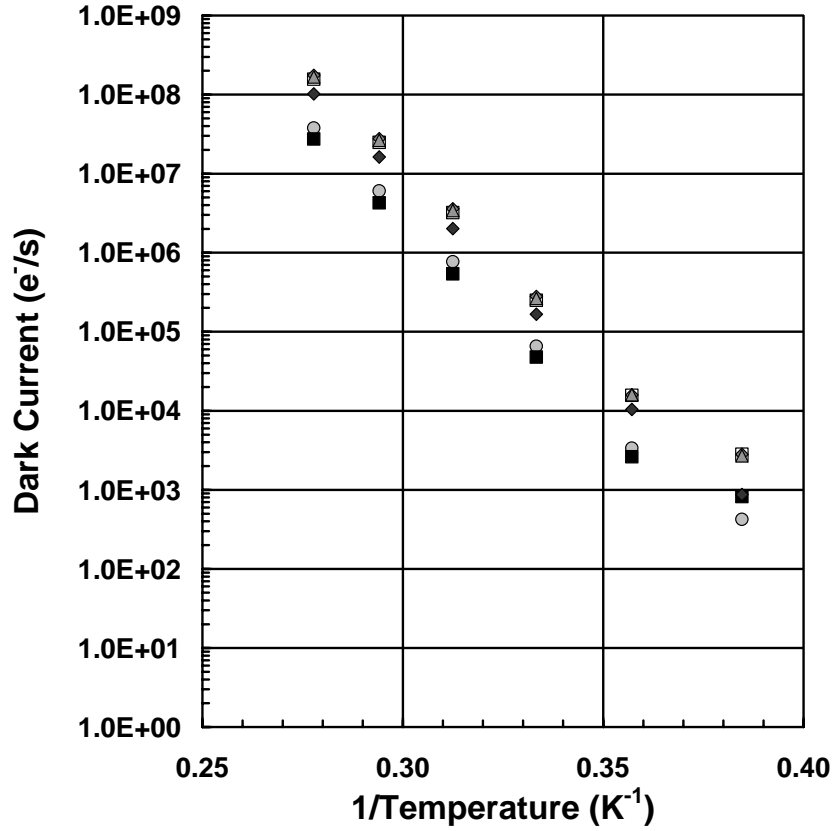


Figure 2: Dark current as a function of inverse temperature for several pixels. The detector bias is 200 V m^{-1} for all measurements.

‘reverse bolometer’ stimulators⁵ are used to illuminate the array. Two 45° fold mirrors direct the radiation onto the array. The stimulators are not calibrated and therefore cannot be used to determine figures of merit such as responsivity and NEP. We are in the process of replacing one of the stimulators with an internally mounted filtered blackbody. We have designed the blackbody to shine $\sim 10^8 \text{ photons s}^{-1}$ at $96 \mu\text{m}$ ($\Delta\lambda=31.25 \mu\text{m}$)¹, simulating the expected flux for airborne conditions.

The array temperature is controlled using a closed loop system. We are using a LakeShore Model 330 temperature controller with a silicon diode temperature sensor and a cartridge heater. The detector array is thermally isolated from the helium bath using G10 standoffs. Thermal conduction to the array is controlled by a specially designed cold strap between the array assembly and the helium bath. This setup allows us to control the array temperature to $\pm 10 \text{ mK}$.

DISCUSSION

At this point in our work we have measured the dark current as a function of temperature for all 48 detectors in the array. Figure 2 shows the dark current for several pixels. Measurement were made at a detector bias of 200 V m^{-1} . Our results are consistent with values determined by Reference 1.

There are significant variations in the dark current for our detectors. It is observed to be vary by nearly a factor of 10 from the largest to smallest value. Also, the relative responsivity correlates well with the dark current. However, we have ascertained that the dewar is quite dark. Blanked-off pixels give the same dark current as those seeing the interior of the helium shroud. To examine this variation, we have plotted the log

of the dark current versus the inverse of the temperature in Figure 2. The straight line relationship at the higher temperatures implies

$$I_{dark} \propto e^{-E/kT}, \quad (1)$$

the dark current is proportional to a Boltzmann factor. Here E is the energy of thermal excitation. From a fit to the data, we determined $E \sim 0.01$ eV. This corresponds to the ionization energy of shallow acceptors in Ge⁷. Such behavior is consistent with the production of the dark current in the bulk of the material. Surface conduction might be expected to have a less consistent behavior because the detector surfaces are subject to non-uniform treatment.

Work continues on the prototype array. Reference 1 note Ge:Sb detectors should provide equal sensitivity to Ge:Ga detectors for high background applications such as airborne astronomy. With the installation of the internal blackbody source, we will determine the detector responsivity, NEP and DQE. We believe this technology will be promising for applications in airborne astronomy.

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